

More About Weather Satellites

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Introduction

Instead of trying to present all the possible (and impossible) questions and answers that will come up in the presentation, I will briefly describe the weather satellites, covering most of the topics likely to come up.

Different Orbits for Different Purposes

Weather satellites are specially designed for their intended purposes:

- capturing images,
- measuring Earth and atmospheric factors, and
- developing data and imagery in a timely way to present to the public, as well as provide data for weather forecasting.

There are two sets of satellites:

- Polar-orbiting Operational Environmental Satellites (POES) and
- Geostationary Operational Environmental Satellites (GOES).

Each type carries a large number of instruments. We will not try to describe all of these. You may refer to the listings at the end of this report.

The **polar satellites** are in an orbit that travels over the North and South Poles, completing one orbit each 102 minutes. During this time, Earth moves under the satellite about 1500 miles at the equator. The imager scans across the orbital path with a scan width of 1500 miles, providing contiguous scan data as the day goes on. As the satellite goes north and south, it scans the whole Earth twice each day. The orbiting is timed to scan at a given time over each spot on the Earth, such as 7:30 AM and 7:30 PM. A second satellite is in the same orbit, but timed to pass over the same area at 2:30 AM and 2:30 PM, providing high-resolution data for accurate forecasting.

The **geostationary satellites** are in an orbit that circles the equator every 24 hours. At that altitude and rate, it appears stationary over one spot on the equator. This type of orbit permits controlled scanning of the Imager to view any portion of the visible hemisphere on demand. Full Earth or partial Earth images may be developed. This feature is particularly helpful when the Imager is tracking a storm, with images in short periods allowing tracking in real time.

Altitude and Velocity Issues

The altitude of a satellite is determined by the need to be above the atmosphere. The density of air decreases with altitude at a rate of 90% reduction for each 16 miles of altitude. Planes fly at 30,000 feet to make use of the lower drag at that altitude. A satellite at 100 miles altitude will still be affected by the air and will be slowed down so much that it may last only a few months. The polar satellite at 550 statute miles has a lifetime of tens of years, and the geostationary one at 22,300 miles has virtually limitless life with respect to air drag.

In order to maintain altitude and not fall to Earth, the satellite must have a certain velocity. The velocity decreases with altitude and the length of its path around the Earth increases, such that a higher altitude satellite will take longer to orbit. The POES satellite at 470 miles travels at a ground velocity of 16,672 miles per hour. The GOES satellite travels at a velocity of 6,872 miles per hour.

Weather Sensors

The sensors on the imaging systems are very small, 0.02 inches or less for each of five channels (or wavelengths). They are made of semiconductor material that changes resistance with temperature. In order to become extremely sensitive they must be cooled to near 100 degrees Kelvin (that's minus 173 degrees Celsius or minus 280 degrees Fahrenheit). For the sensors to be this cold, they are mounted on insulators and attached to black panels, which are exposed to deep space (essentially zero Kelvin). They radiate their heat to space to achieve the desired temperature. At that temperature they are able to detect changes in Earth temperature of less than 0.2 degrees Celsius.

The sensor is at the focal point of a telescope having a field of view designed for that instrument. On the POES, the telescope focuses the sensor on a circular area only 0.7 miles in diameter on the Earth's surface. For GOES, that area may be near 0.6 miles in diameter on the surface for imagery in the visible portion of the spectrum. In the infrared portions, the resolution is larger. This resolution permits recognition of small clouds that are separated by only this distance. Selection of sensor material and color filters control the spectral range for each sensor. Some are set for the visible region, others are designed for the infrared range where variation in radiated heat from each spot of the Earth may be measured. This feature permits the imager to view cloud location throughout the night.

Each sensor views the Earth through a stationary telescope focussed on Earth. The telescope looks at a large mirror, which directs its view to selected locations on Earth. In the case of POES, the mirror simply scans back and forth across the orbital path, generating lines of data, which build up a scene using the motion of the spacecraft as the second axis. In the GOES, the mirror has two axes of scan to generate images from the whole Earth or any part of it. The POES telescope has an 8-inch aperture and the GOES telescope has a 10-inch aperture.

Communication with the Ground

Signals from the sensors are amplified and digitized and sent to a transmitter. In the case of GOES, the transmitter antenna is directed to a fixed ground receiving station such as Wallops Island, Virginia, where the received information is passed on to the Weather Service at Suitland, Maryland. From there, data in many forms are passed on to users all over the world. The POES system is not so simple. Since the satellite is moving around the Earth continuously, the data must be stored in a recorder and transmitted rapidly to a *primary* ground receiver in Alaska as it passes over the North Pole each orbit. From there it is relayed to Suitland for processing and distribution.

Spacecraft Body

The body of the spacecraft is designed as a flexible platform for the set of instruments planned for that mission. The body of the POES is approximately 14 feet long with a diameter of 6 feet. It holds as many as seven different instruments plus a search-and-rescue system. The body is stabilized to look at the Earth during its orbit. The solar panel is rotated to have its collectors facing the sun at all times. The body of the spacecraft and all instruments have multi-layer foil-like insulation to protect them from the heat of the Sun and have thermal control systems to maintain the operating systems near constant temperature.

The GOES spacecraft is a box structure approximately 10 feet on a side, with a large solar panel to one side. In addition to the instrument packages, there is a rocket system in the center, which is required to put the spacecraft into a circular orbit after the launch booster brings it to the proper altitude. Several means for maintaining directional stability are used, including small thrusters on each side of the body.

Launch

Neither of the systems is launched on a Space Shuttle. The POES is launched on a Delta II vehicle from Vandenberg Air Force Base. This base is in California, on a promontory near Santa Barbara where the launch may be made directly south without endangering any population. The time of the launch is set to be most efficient in putting the spacecraft into the proper orbit at the time desired.

The GOES is launched on a Delta IV rocket from Cape Canaveral Air Force Station on the north Florida coast where the launch directly east may be made safely. Since the launch site is not on the equator some correction must be made once in orbit to put it on the equatorial orbit. The launch vehicle goes into a high elliptical orbit, reaching 22,300 miles at its highest. At that point the spacecraft is released and uses its own propulsion system to put it into a perfectly circular orbit. It must maintain a fixed location in that orbit, since it is sharing space with communication, TV relay, and other satellites. There may be as many as 600 satellites in geostationary orbit at one time.

Satellite Longevity

The lifetime of the satellite is determined by the amount of fuel available for orbit correction maneuvers or by the failure of a critical part of the system. Some of the POES have had operational lives of over 8 years and extended service for as much as 14 years. Some of the GOES have remained useful for up to 20 years. This longevity has provided the National Weather Service with an excellent continuing set of data collection systems and has greatly enhanced the ability to provide immediate imagery and data and more accurate and extended time estimates of future weather conditions.

E. K. 3/23/05

For More Information

NOAA-N, U.S. Dept. Commerce, NOAA, NESDIS, NP-2004-8-666-GSFC

GOES-NO/P/Q The Next Generation, U.S. Dept Commerce, NOAA, NESDIS, NP-2001-7-324-GSFC

<http://goespoes.gsfc.nasa.gov>